An Autonomous Glider Network for the Monterey Bay Predictive Skill Experiment / AOSN-II

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LONG-TERM GOALS

Our long-term goal is to develop an efficient, relocatable, infrastructure-free ocean observing system composed of high-endurance, low-cost gliding vehicles with near-global range and modular sensor payload. Particular emphasis is placed on the development of adaptive sampling strategies and the automated control of large glider fleets operating within the framework of an autonomous oceanographic sampling network.

OBJECTIVES

This work is one component of a coordinated effort to demonstrate and quantify gains in predictive skill resulting from model-guided adaptive sampling using a network of autonomous vehicles. During the summer 2003 AOSN-II field experiment the WHOI glider fleet will provide distributed measurements of temperature and salinity, vertically-averaged velocity, chlorophyll fluorescence, optical backscatter, and PAR. The specific objectives are to (1) Construct and operate a ten-member fleet of autonomous gliders capable of 30-day operation and Iridium satellite communications, (2) Develop and test, in collaboration with colleagues, the necessary vehicle control protocols to enable model-driven repositioning of the glider fleet during the field experiment, and (3) Develop and deploy new glider-based bio-optical sensors to complement the existing physical oceanographic sensor suite.

APPROACH

Our primary contribution to this effort is the construction and operation of a network of autonomous gliders. We will operate the glider fleet, collect and quality-control the glider-derived oceanographic measurements, and perform basic interpretive analyses in near-real-time. We will take primary responsibility for the post-experiment analysis of the data collected by the gliders and, with our collaborators, synthesize this information with data from other ongoing investigations. Adaptive reconfiguration of the fleet during the course of the experiment will be directed by a synthesis of available observations and model results in combination with fleet control algorithms developed by Naomi Leonard (Princeton) and colleagues.

WORK COMPLETED

Ten electrically-powered gliders were constructed to WHOI specifications by Webb Research Corp. All vehicles were equipped with Iridium communications systems and a Sea-Bird CTD. As each new vehicle was completed and delivered to WHOI it was subjected to a series of acceptance trials before being incorporated into our ongoing testing program in Buzzards Bay. A new fiber-optic photosynthetically-active radiation sensor developed at WHOI was installed on the gliders, as was a new power and data interface. Twelve WetLabs bb2f fluorometer/backscatter sensors were procured, one for each vehicle in the WHOI glider fleet. These sensors were installed and tested. Software required to integrate the new sensors into the glider's data stream was implemented and tested.

Upon arrival at MBARI for the AOSN-II experiment each vehicle was prepared for final check-out and deployment. Several dives were made in the MBARI test tank prior to the first at-sea deployment on 21 July. Between 29 July and 31 August we maintained a background observing grid consisting of five 50-75 km rectangular circuits situated to best observed the development and decline of cold upwelling plumes associated with time-varying alongshore wind forcing.. This grid was occupied by 4-7 vehicles at any given time during this period. Each glider surfaced every two hours to obtain a GPS position and transmit collected data via Iridium. This data was automatically quality-controlled, converted into a standard vertical profile format, and distributed via ftp to other AOSN-II participants. As vehicles exhausted their batteries they were recovered, repowered, and redeployed. We maintained this mode of operation until the final vehicle was recovered on 31 August.

In addition to the background grid observations, several single- and multi-vehicle experiments were performed in collaboration with Naomi Leonard and her colleagues. These experiments stressed coordinated multi-vehicle maneuvering to efficiently measure and respond to ocean property gradients.

RESULTS

A unique dataset consisting of more than 10,000 vertical profiles was collected during a one-month period. Due to rigorous pre-deployment calibration using our the new Sea-Bird reference sensors (procured under a related DURIP award) the quality of the CTD data collected during AOSN-II was excellent and directly comparable to shipboard CTD measurements. The new bio-optical sensors performed extremely well. Two complete upwelling/relaxation cycles were observed by the glider fleet. Horizontal scales ranging from a few hundred meters to 25+ km were simultaneously measured. Preliminary indications are that roughly 90% of placed calls were successful. Our automated control and data management system worked flawlessly. Model-based adaptive sampling was not possible due to the generally unrealistic representations of the circulation and tracer fields in both the HOPS and ROMS models.

Glider performance was generally good with typical survey performance of 20-25 km per day in an ocean environment characterized by strong (25-50 cm/s) tidal fluctuations. Iridium communications was both slow and energy intensive but generally robust. Preliminary results suggest that better than 90% of expected surface contacts via Iridium were completed. New methods for compression or data decimation need to be explored in order to reduce the volume of transmitted data. Endurance was less than anticipated due primarily to excessive Iridium use. Typical endurance was 15 days with alkaline batteries. Research into more efficient operational modes and alternative power sources (e.g. lithium primary batteries) is ongoing.

IMPACT/APPLICATIONS

Continued development of multi-vehicle network operations will enable efficient measurement of transient ocean phenomena such as mesoscale eddies and fronts and streamline distributed environmental observations in remote or hostile locations. A network of gliding vehicles will supply, in an efficient and cost-effective manner, high-quality, near-real-time environmental information for operational ocean/atmosphere forecasting and model validation.

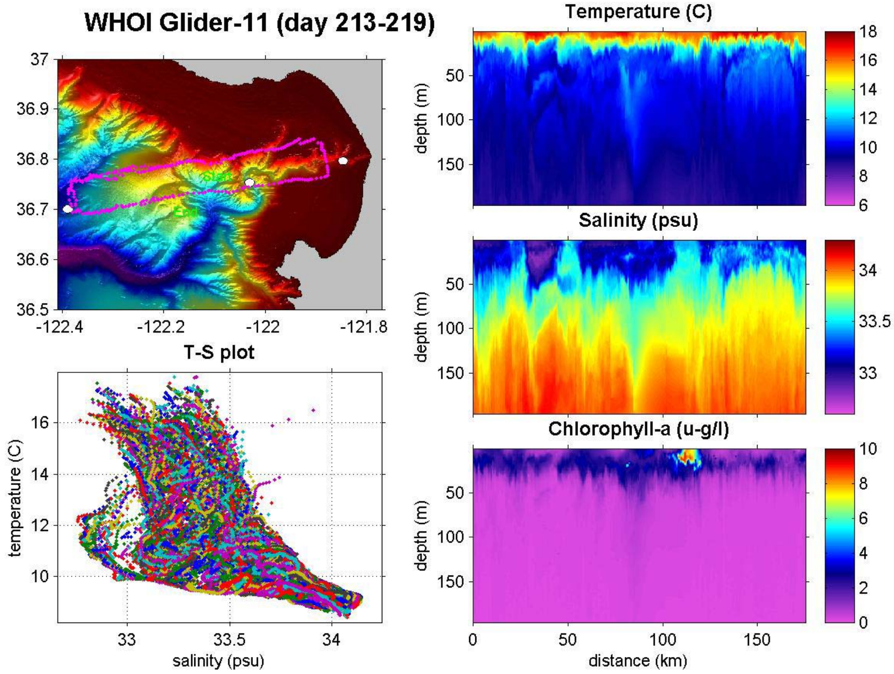

Figure 1: Example data collected during the AOSN-II experiment in August 2003 by one of ten WHOI gliders. This vehicle covered approximately 180 km of trackline in seven days. Water depths range from 50 m to greater than 2000 m. Vertical measurement resolution is approximately one meter. This figure was created by a team of MBARI interns and postdocs as part of a data visualization project. Similar figures appear on the AOSN-II web site for all WHOI and SIO gliders.

RELATED PROJECTS

The following is an exhaustive list of projects related to the AOSN-II effort:

Implementing FORMS (Feature oriented regional modeling system) for the Monterey Bay forecasting system using HOPS and ROMS.
Avijit Gangopadhyay.
N00014-1-0206

Development of a Monterey Bay Forecasting System Using The Regional Ocean Modeling System (ROMS)
Yi Chao
N00014-03-1-0208

Adaptive sampling during AOSN-II
PI: S. J. Majumdar
N00014-03-1-0559

Deep Autonomous Gliders for the "Autonomous Ocean Sampling Network II' Experiment
Russ E. Davis, Jeffrey T. Sherman
N00014-03-1-1049

Coastal Bioluminescence: Measurement and Prediction
J.F. Case
N00014-97-1-0424
Grant Supplement, Mod. 13

Aerial Surveys of the Atmosphere and Ocean off Central California
N0001403WR20002
N0001403WR20006

S. R. Ramp, J. D. Paduan, W. Nuss, and C. A. Collins
Hyperspectral Radiometer for Airborne Deployment
N0001403WR20209
S. Ramp

High-Resolution Measurement of Coastal Bioluminescence: II. Improving short-term predictability across seasons
Steven Haddock
N00014-00-1-0842

QUANTIFICATION OF LITTORAL BIOLUMINESCENCE STRUCTURE AND INDUCED WATER LEAVING RADIANCE
Mark Moline
N00014-03-1-0341

Use of a Circulation Model to Enhance Predictability of Bioluminescence in the Coastal Ocean
Igor Shulman
Naval Research Laboratory, Grant Number: N00014-03-WX-20882 and -20819
Leslie Rosenfeld and Jeffrey Paduan
NPS, Grant Number: N00014-03-WR-20009
Dennis McGillicuddy
N000140210853

Participation in AOSN II
A. Healey
N0001403WR20063

Autonomous Ocean Sampling Network II (AOSN II): System Engineering and Project Coordination
J. G. Bellingham and P. Chandler
N00014-02-1-0856
Underwater Glider Networks and Adaptive Ocean Sampling

Naomi Leonard, Clarence Rowley, and Jerrold Marsden
N000140210826

Underwater Glider Dynamics and Control
Leonard (PI)
N00014-02-1-0861

Autonomous Ocean Sampling Network II: Assessing the Large Scale Hydrography of the Central California Coast
Margaret A. McManus and Francisco Chavez
N000140310267

An Autonomous Glider Network for the Monterey Bay Predictive Skill Experiment / AOSN-II
David M. Fratantoni
N000140210846

Instrumentation in support of autonomous glider operations.
David M. Fratantoni
N00014-03-1-0736

Glider communication and sensor enhancements in support of AOSN.
David M. Fratantoni
N00014-02-1-0846

Development of a Regional Coastal and Open Ocean Forecast System:
Harvard Ocean Prediction System (HOPS)
(Included under this are "Quantitative Interdisciplinary Adaptive Sampling OSSEs for Monterey Bay and the California Current System - AOSN-II" and "Adaptive Sampling OSSEs for Monterey Bay and the California Current System - AOSN-II")
A.R. Robinson
N00014-97-1-0239

Monterey Bay Sampling.
Craig Bishop
N0001403WX20009